Warp Drive Laboratory Experiment: Proposal for Detecting Engineered Spacetime Curvature

Goal: demonstrate a reproducible, man-made, weak spacetime perturbation synchronized to a modulated stress-energy source. This is not propulsion; it is a proof-of-principle detection of artificial curvature—the first rung toward warp technologies.

Concept

Place a high-finesse optical cavity (or Michelson arm) adjacent to a rapidly modulated mass distribution. The Newtonian potential $\Phi(t)$ at the cavity modulates the proper time/optical path length, producing a tiny phase modulation at the drive frequency. Detect via lock-in/matched filtering.

Key Relations (weak-field)

Inside a weak gravitational potential Φ, proper time rate $\approx (1 + \Phi/c^2)$. Optical phase over length L is $\phi = (2\pi/\lambda)\cdot L$. A small potential modulation $\delta\Phi$ yields phase modulation $\Delta\phi \approx (2\pi/\lambda)\cdot L_eff\cdot(\delta\Phi/c^2)$, where $L_eff \approx (F/\pi)\cdot L$ for a cavity of finesse F.

Order-of-Magnitude Numerical Example

Laser wavelength λ	1550 nm
Cavity length L	1.0 m
Finesse F	300
Effective path L_eff	$\approx F\cdot L/\pi \approx$ 95.5 cm × 300/$\pi \approx$ 95.5 m (here computed exactly)
Rotor masses	2 × 50 kg at radius 0.5 m
Rotation frequency	10 Hz (dominant harmonic at 20 Hz)
Closest arm distance	r■ ≈ 0.7 m from rotor center

Computed potential modulation amplitude at 2f: ~ 4.86e-09 J/kg; phase modulation amplitude $\Delta\phi \approx$ 2.09e-17 rad; equivalent displacement $\Delta L \approx$ 5.16e-24 m.

Interpretation: with modest lab masses, the signal is exceedingly small (≈5×10■²■ m equivalent). However, techniques from gravitational-wave detection—resonant cavities, long integration, and synchronous detection—can place meaningful upper limits or reveal a signal if we scale the source (larger mass, closer approach, higher finesse).

Step-by-Step Experimental Plan

1) Design geometry in CAD/FEA: locate the optical cavity within ~0.3–1.0 m of a balanced two-mass rotor. Include vibration isolation stacks and an acoustic enclosure.

2) Source & drive: construct a precision rotor with two opposite masses (50–200 kg each), magnetic bearing or ultra-low-vibration bearings, and a phase-locked motor controller (10–50 Hz). Ensure dynamic balancing to <10■■ g at the cavity location.

3) Optics: build a 1550 nm cavity (L≈1 m) with finesse F≥300 (stretch goal F~1000). Use low-thermal-noise mirrors and active length control (Pound–Drever–Hall lock).

4) Sensing chain: photodiode readout at the cavity transmission, demodulate at the commanded harmonic (2f) with a lock-in amplifier; record raw time series for matched filtering.

5) Environmental vetoes: co-located seismometer, accelerometers, magnetometers, microphones; feed into veto logic to exclude spurious couplings.

6) Calibration: inject known phase modulation via EOM or piezo mirror dither to establish phase-to-voltage transfer and absolute sensitivity.

7) Data run: acquire hours–days of data while sweeping rotor frequency; integrate coherently to improve SNR ~ $\sqrt{T}$.

8) Scaling study: repeat with increased mass (up to safety limits), smaller stand-off distance, and higher finesse to verify $\Delta\phi \propto M$ and $\propto L_eff$.

9) Analysis: estimate upper limits on engineered curvature ($|\Phi|/c^2$) and compare with GR prediction; publish null or detection limits.

Bill of Materials (indicative)

Item	Spec	Qty
Laser	1550 nm, narrow-linewidth (<1 kHz)	1
Optical cavity mirrors	HR @1550 nm, R>99.9%, 1 m spacing hardware	2
Vacuum beamline	1 m vacuum tube + viewports + pumps (optional but recommended)	1
Electronics	EOM, PDH lock controller, photodiodes, lock-in amplifier, DAQ	1 set
Rotor masses	Steel/tungsten blocks, 50–200 kg each	2
Rotor system	Precision turntable, magnetic bearing, motor + encoder	1
Isolation	Optical table, passive/active isolation, acoustic enclosure	1
Sensors	Seismometer, accelerometers, magnetometers, microphones	1 set
Safety	Ballistic shroud for rotor, interlocks, remote operation	—

Risks & Mitigations

• Coupling via vibration/acoustics dominates at 10–50 Hz: mitigate with heavy isolation, phase diagnostics, and null-geometry checks. • Magnetic/electric coupling from the motor: use nonmagnetic components, Faraday shielding, and reference channels. • Rotor failure hazard: design for overspeed containment, interlocks, and remote operation. • Thermal drift in cavity length: use active control (PDH) and temperature stabilization.

Outcome

A null result sets quantitative upper limits on engineered curvature at meter scales; a positive detection would constitute the first laboratory evidence of controllable spacetime shaping by designed stress–energy. Either result is a concrete step toward practical warp engineering.